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G01S 3/78, H04N 7/18

(52) UK CL (Edition J)
H4D DLAB DLFB D244 D72X D733

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None

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(54) Detecting endoscope insertion direction

(57) A method of detecting the direction of insertion of an endoscope sheath (2) comprises the steps of forming from the same endoscope image a sequence of picture-images differing in the number of pixels (or picture elements) and selectively locating a dark region (1, Fig. 12D) in a picture-image of a predetermined number of pixels by successively inspecting the picture-images in the order of those having less pixels, and determining relative to thresholds, the grey levels of the respective pixels in the plurality of said picture-images thus formed, the above-mentioned dark region selected by the above-mentioned selective location step being considered to be the endoscope insertion direction. Preferably, the forming step includes means gradually forming a succession of picture-images of fewer pixels, reducing the number of pixels by a quarter in each step, so that, in the case where the number of pixels is reduced to one quarter, the grey level of one macro-pixel in the picture-image of fewer pixels will be of an average value of the grey levels of the four subsidiary pixels in the 2 x 2 square region in the picture-image of more pixels corresponding to this one macro-pixel.

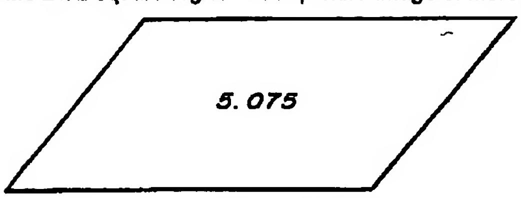

FIG.12(A)

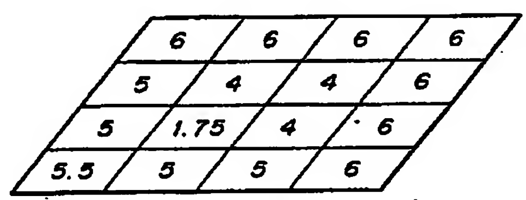

FIG.12(C)

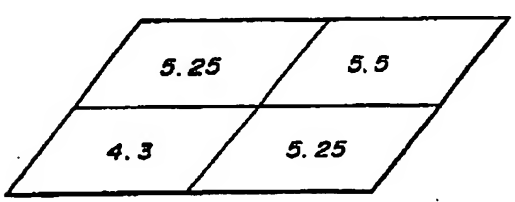

FIG.12(B)

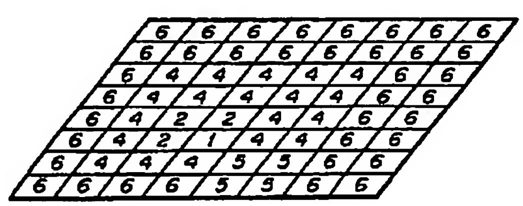

FIG.12(D)

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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FIG.1

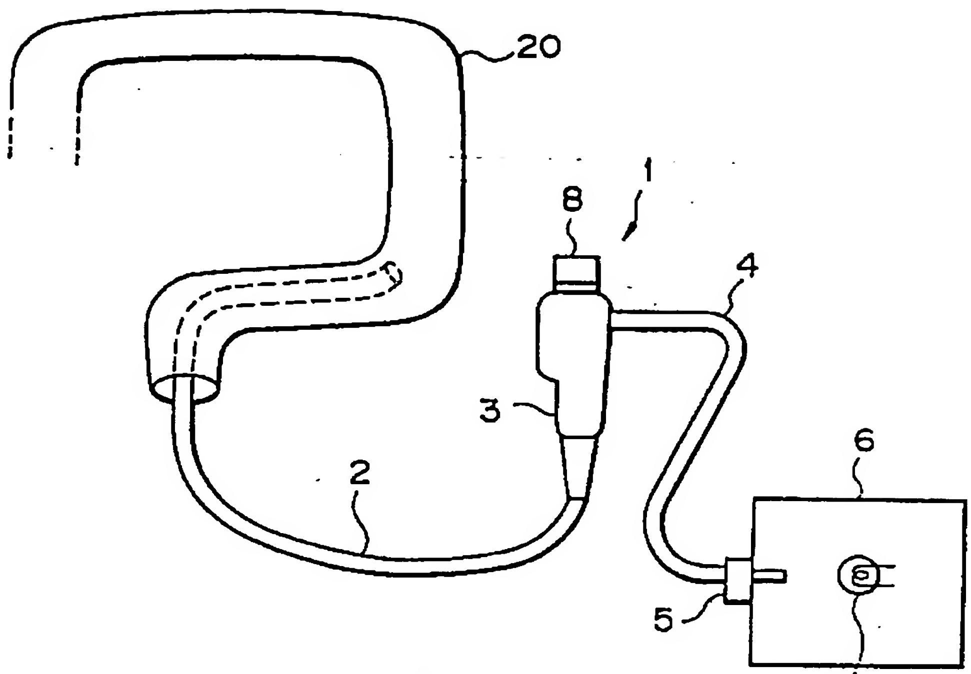


FIG.2

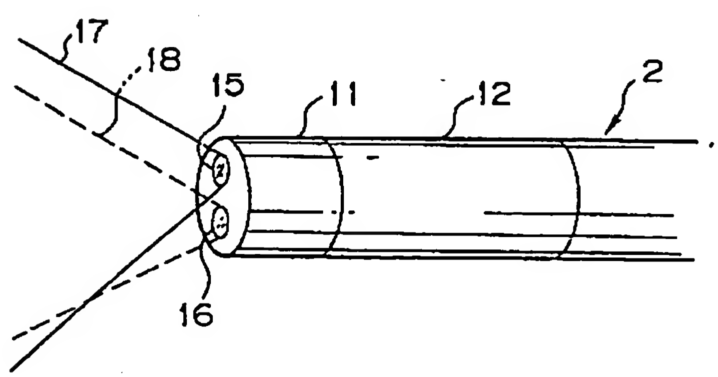


FIG.3

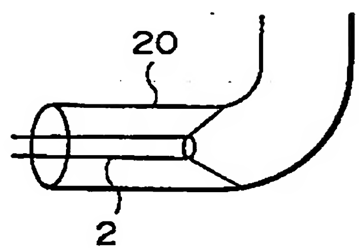


FIG.5

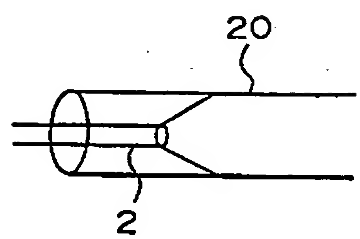


FIG.4

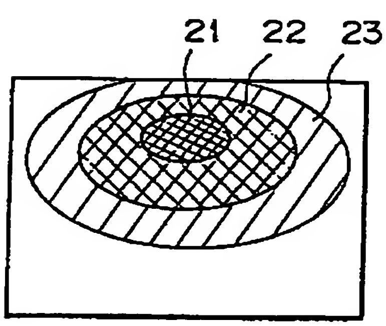


FIG.6

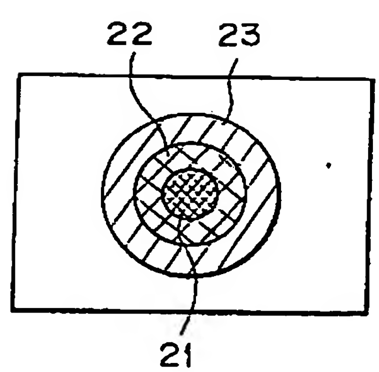


FIG.7

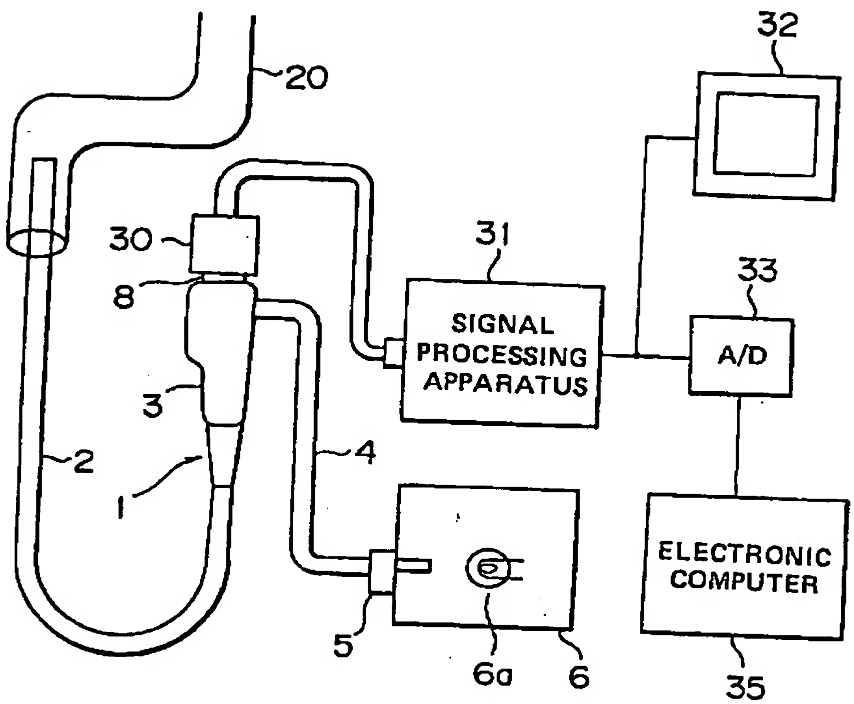

20
32
30
31
8
33
SIGNAL
PROCESSING
APPARATUS
A/D
3
2
4
1
ELECTRONIC
COMPUTER
5
6a
6
35

FIG.8

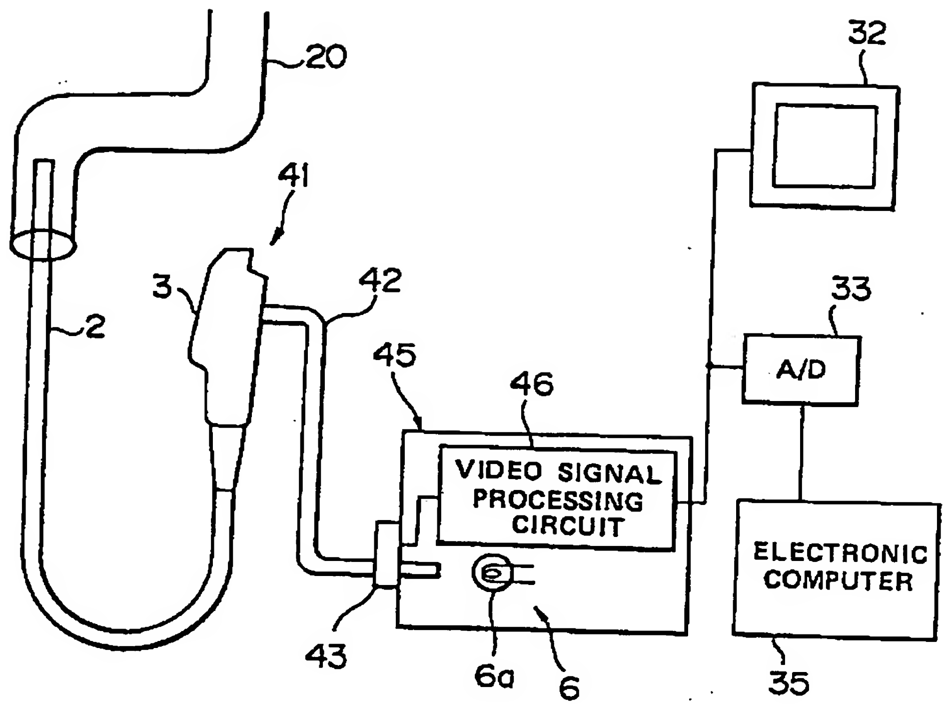

20
2
41
3
42
45
46
VIDEO SIGNAL PROCESSING CIRCUIT
43
6a
6
32
33
A/D
ELECTRONIC COMPUTER
35

FIG.9

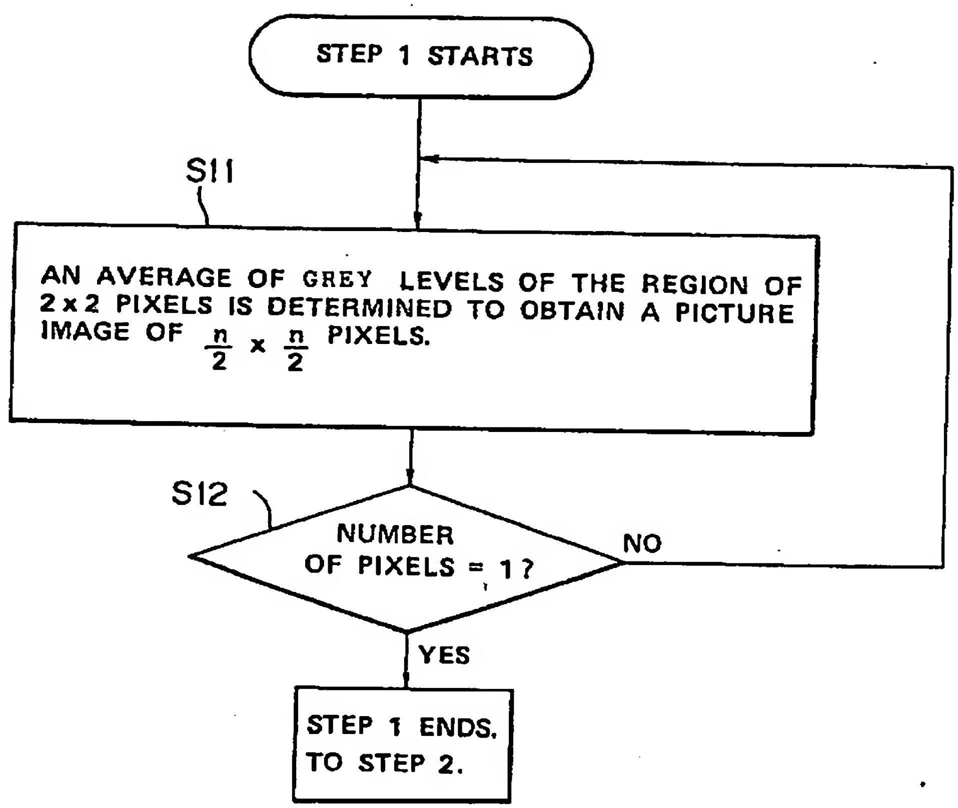

STEP 1 STARTS
S11
AN AVERAGE OF GREY LEVELS OF THE REGION OF 2x2 PIXELS IS DETERMINED TO OBTAIN A PICTURE IMAGE OF $\frac{n}{2} \times \frac{n}{2}$ PIXELS.
S12
NUMBER OF PIXELS = 1?
NO
YES
STEP 1 ENDS. TO STEP 2.

FIG.10(A)

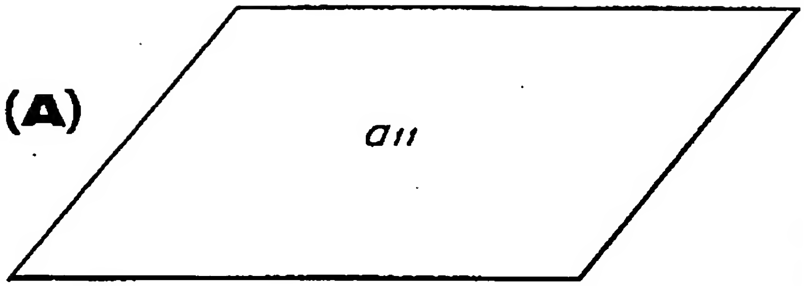


FIG.10(B)

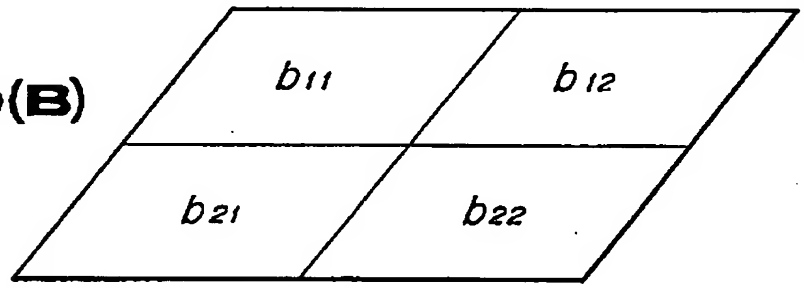


FIG.10(C)

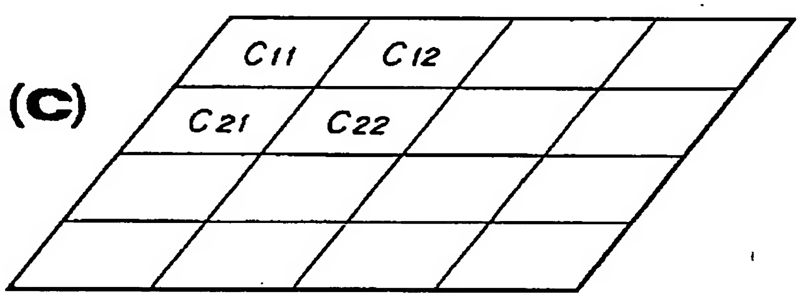


FIG.10(D)

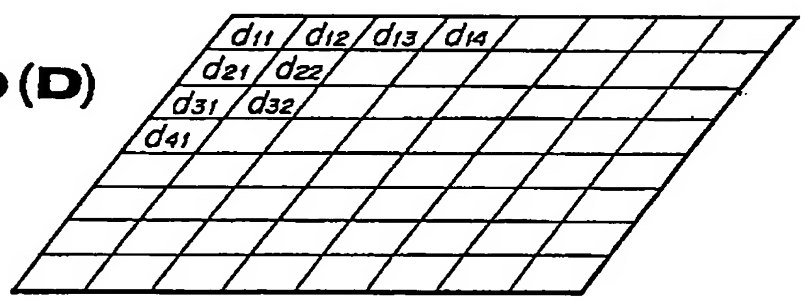


FIG.11

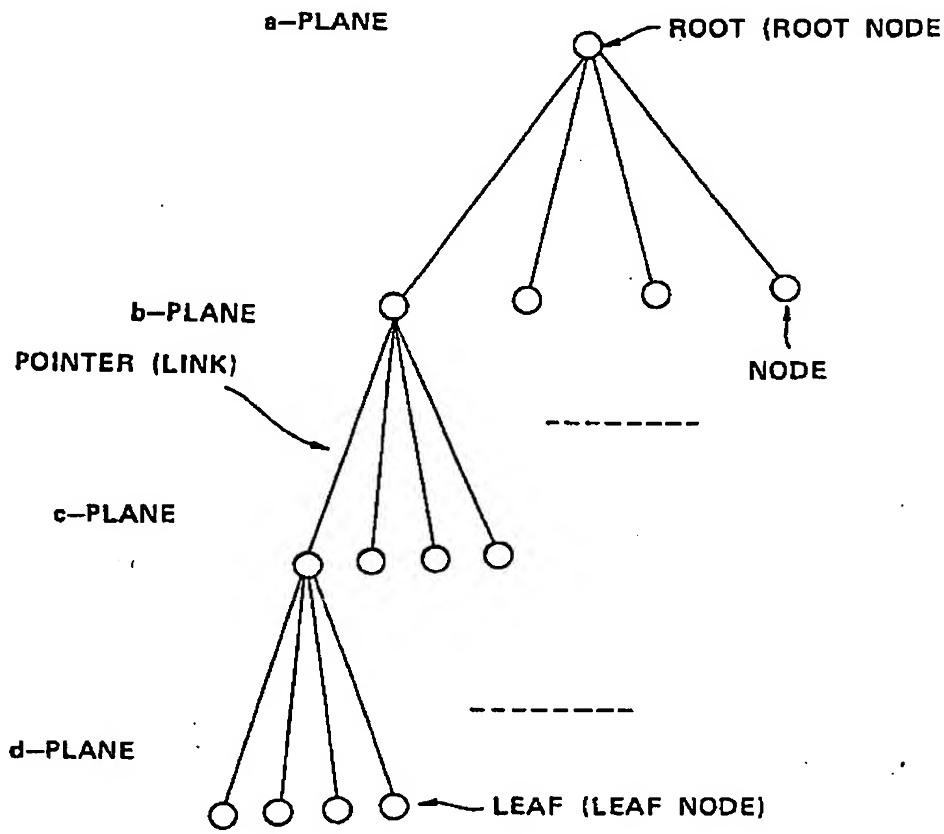

a–PLANE
ROOT (ROOT NODE)
b–PLANE
POINTER (LINK)
NODE
c–PLANE
d–PLANE
LEAF (LEAF NODE)

FIG.12(A)

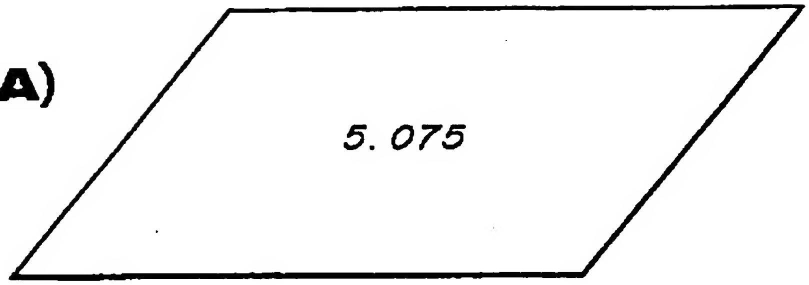


FIG.12(B)

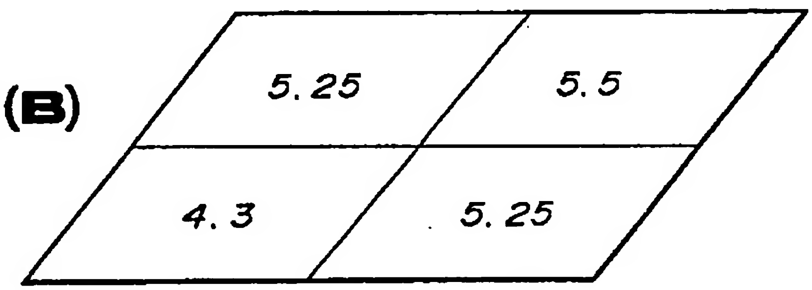


FIG.12(C)

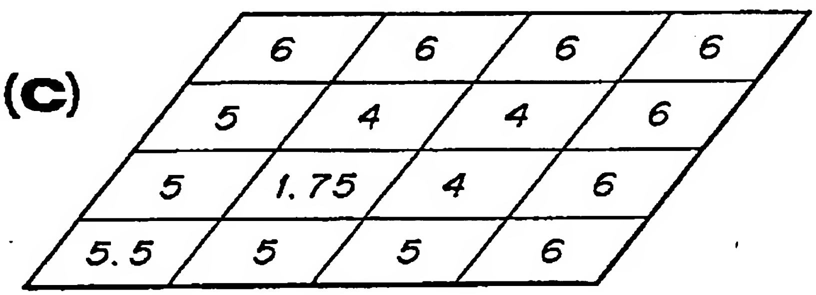


FIG.12(D)

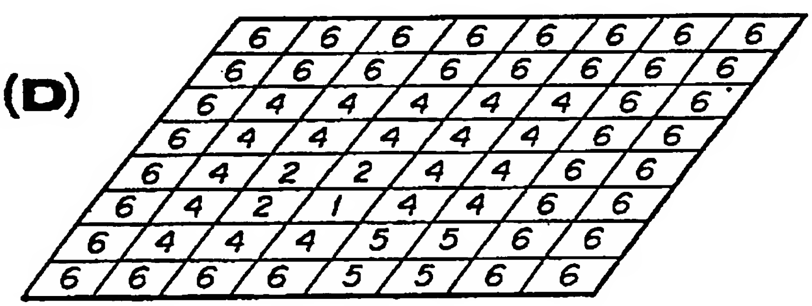


FIG.13(A)

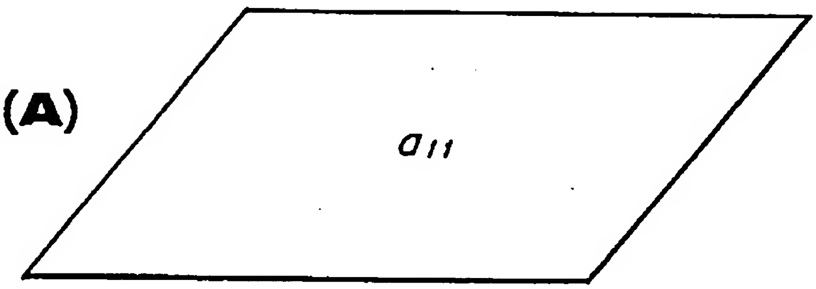


FIG.13(B)

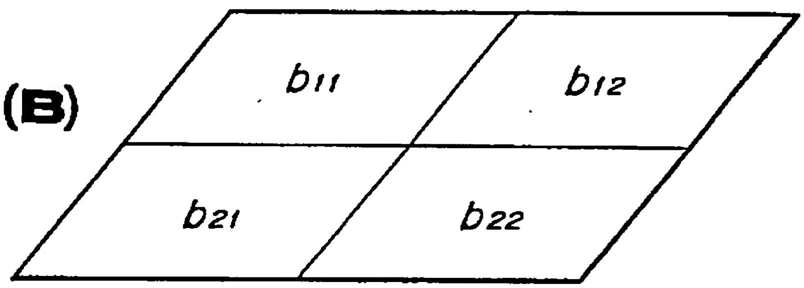


FIG.13(C)

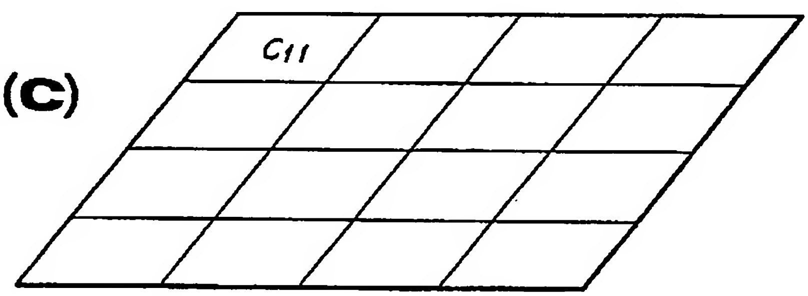


FIG.13(D)

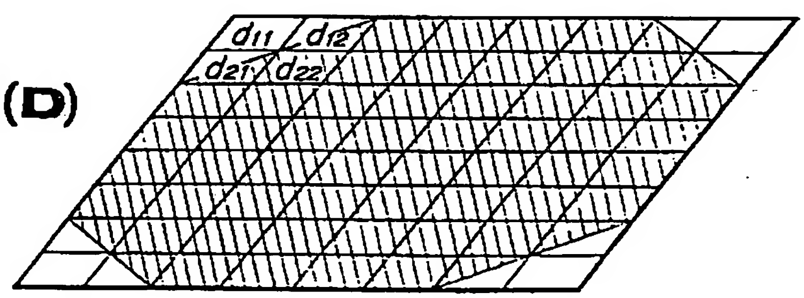


FIG.14

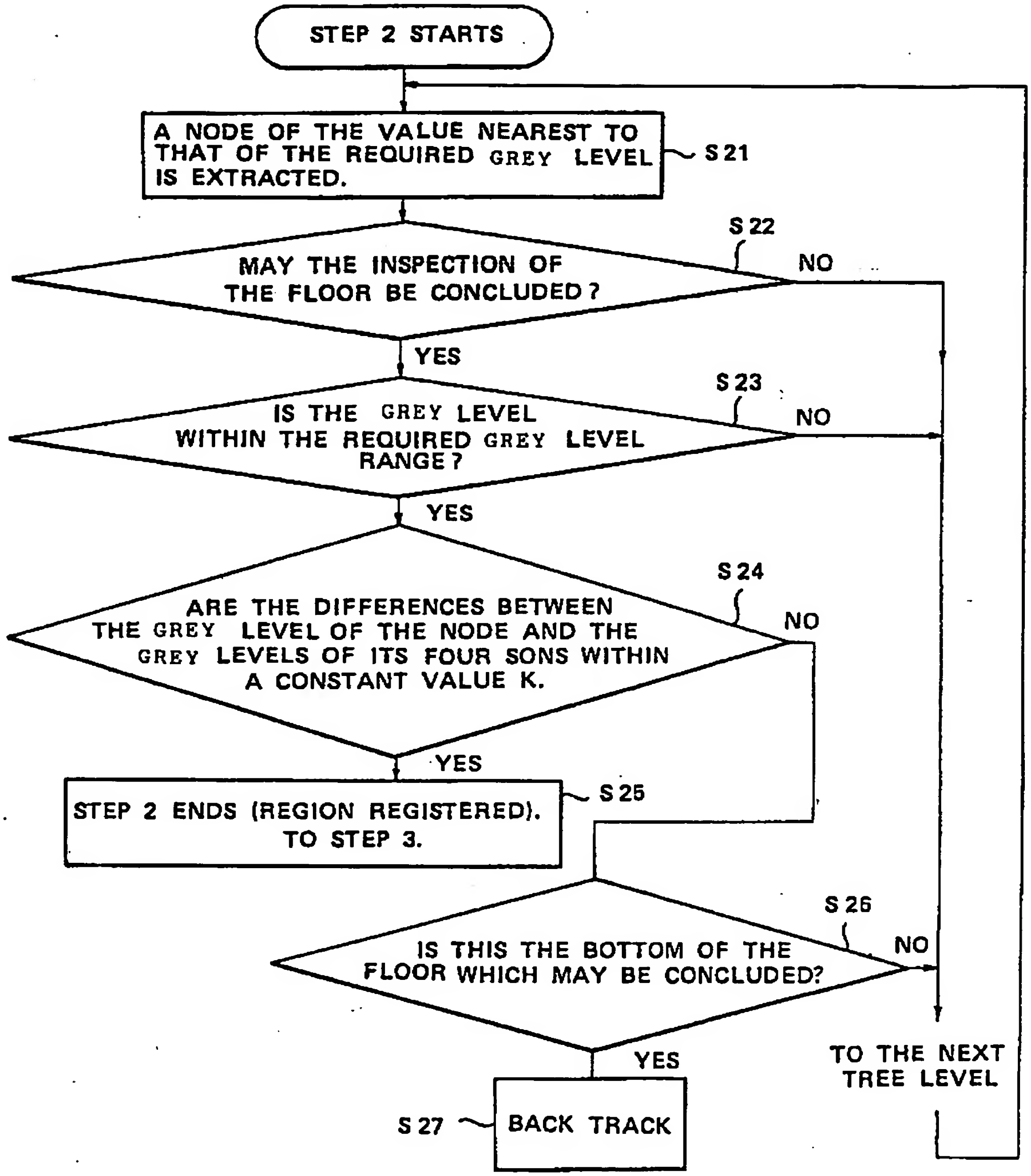
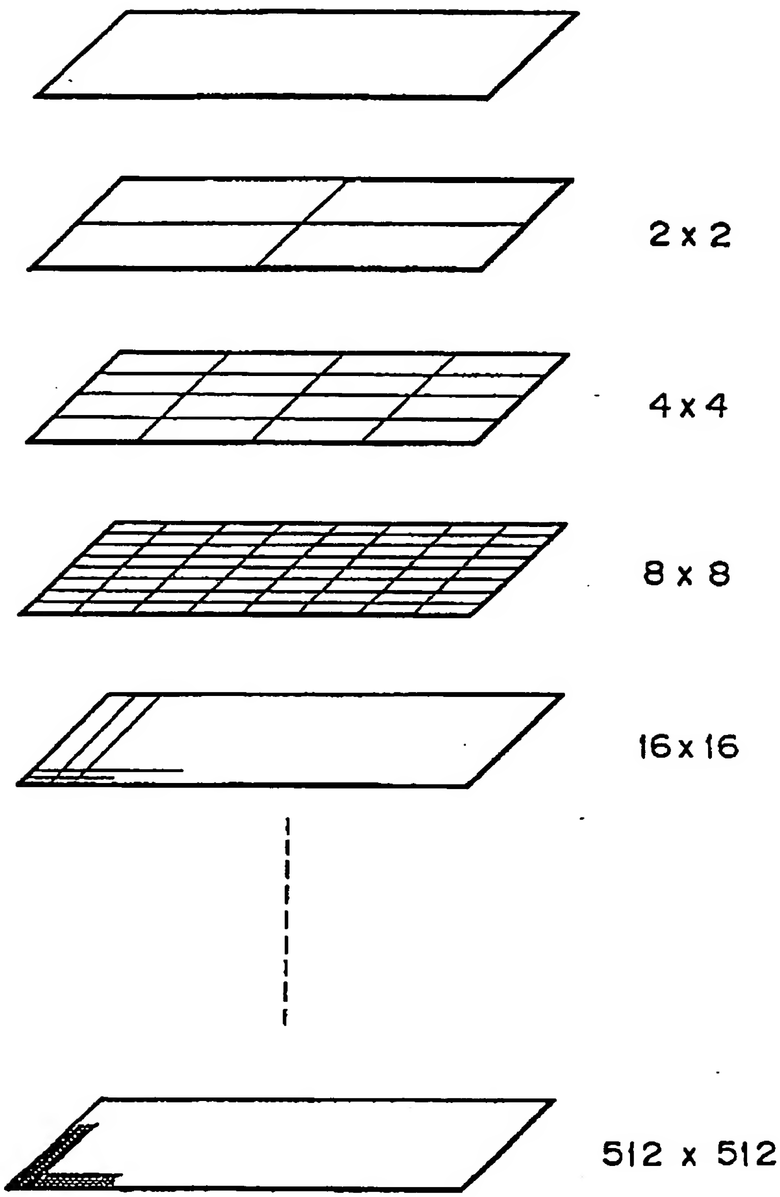

STEP 2 STARTS
A NODE OF THE VALUE NEAREST TO THAT OF THE REQUIRED GREY LEVEL IS EXTRACTED.
S21
S22
MAY THE INSPECTION OF THE FLOOR BE CONCLUDED?
NO
YES
S23
IS THE GREY LEVEL WITHIN THE REQUIRED GREY LEVEL RANGE?
NO
YES
S24
ARE THE DIFFERENCES BETWEEN THE GREY LEVEL OF THE NODE AND THE GREY LEVELS OF ITS FOUR SONS WITHIN A CONSTANT VALUE K.
NO
YES
STEP 2 ENDS (REGION REGISTERED). TO STEP 3.
S25
S26
IS THIS THE BOTTOM OF THE FLOOR WHICH MAY BE CONCLUDED?
NO
YES
TO THE NEXT TREE LEVEL
S27
BACK TRACK

FIG. 15



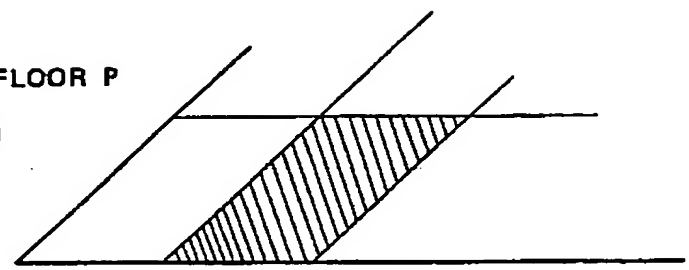


FIG.16(A)

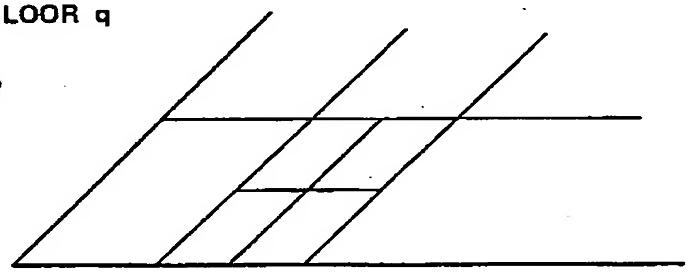


FIG.16(B)

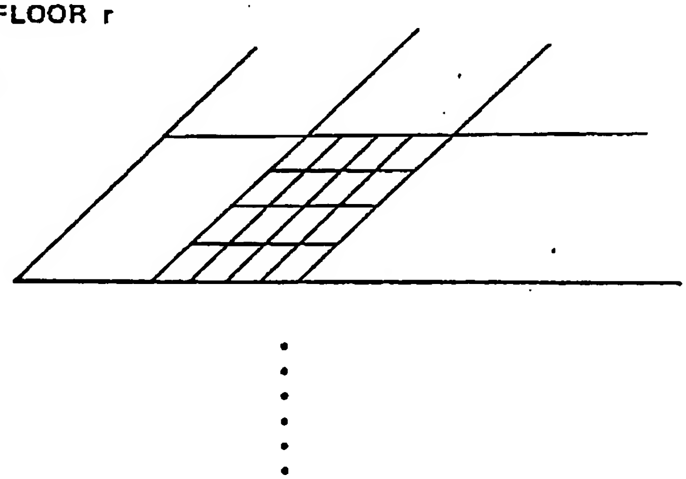


FIG.16(C)

FIG.17(A)

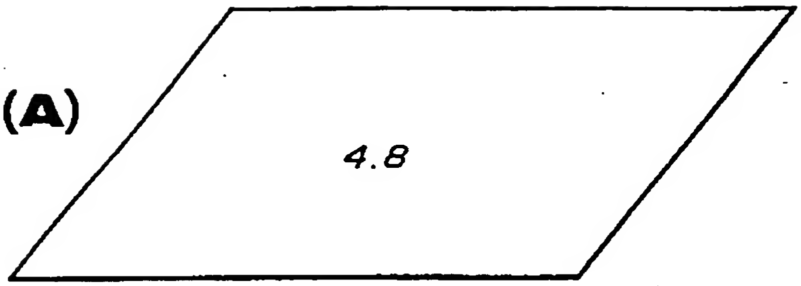


FIG.17(B)

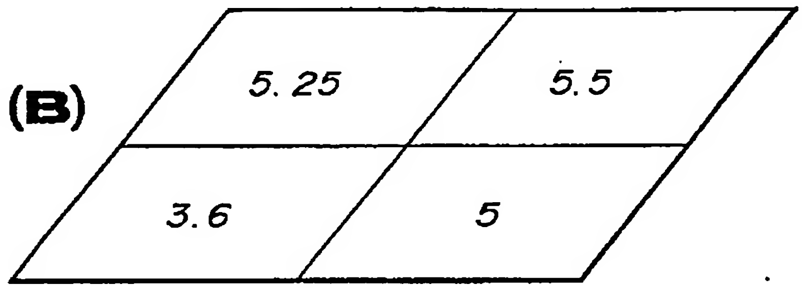


FIG.17(C)

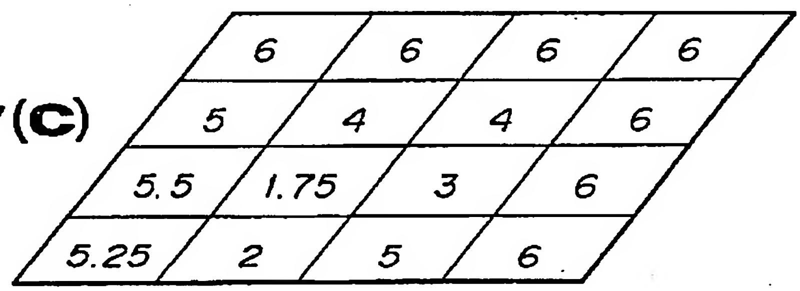


FIG.17(D)

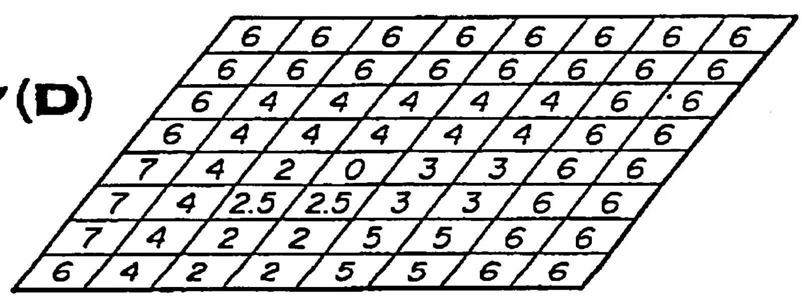


FIG.18

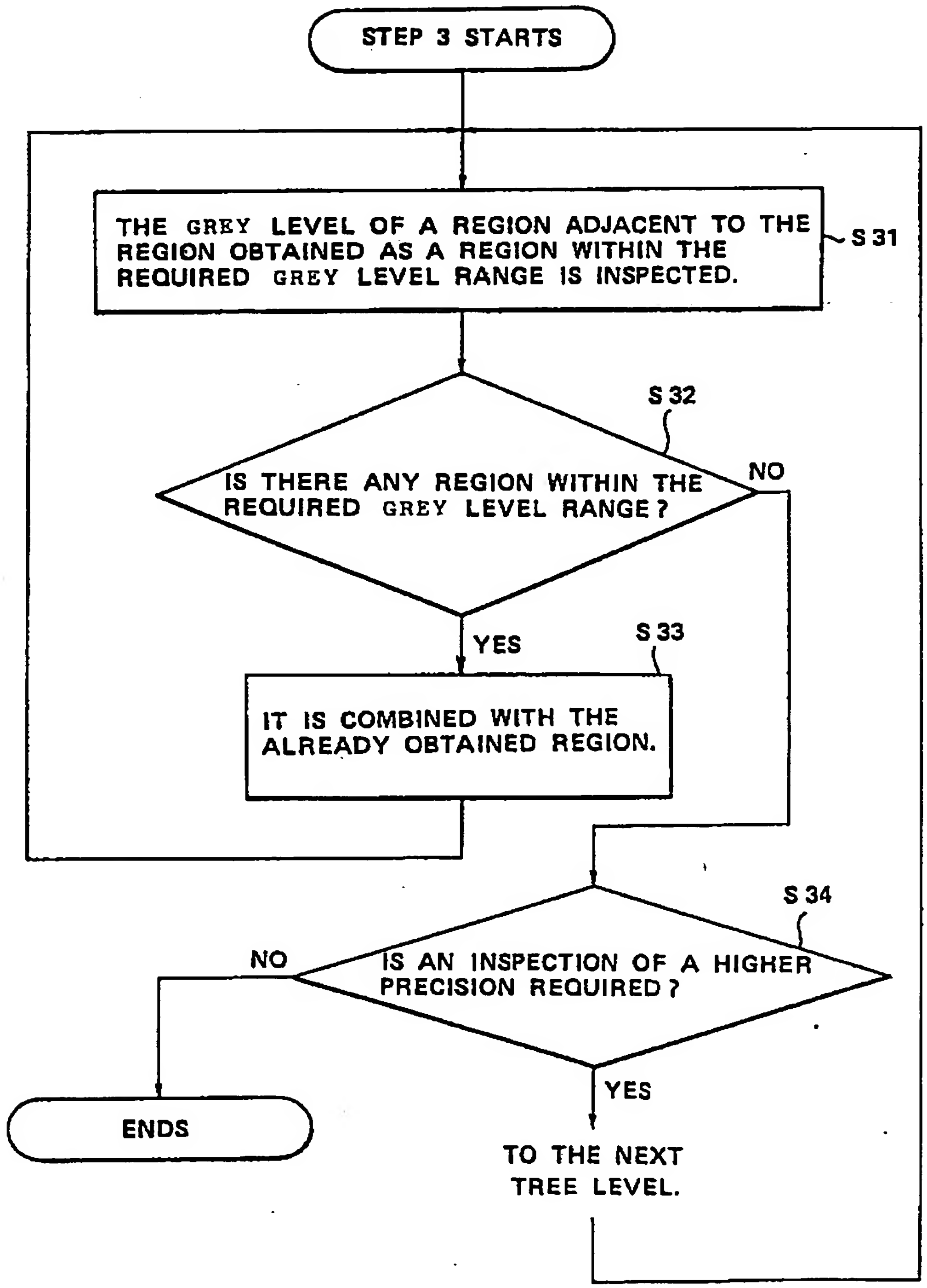

STEP 3 STARTS
THE GREY LEVEL OF A REGION ADJACENT TO THE REGION OBTAINED AS A REGION WITHIN THE REQUIRED GREY LEVEL RANGE IS INSPECTED.
S 31
S 32
IS THERE ANY REGION WITHIN THE REQUIRED GREY LEVEL RANGE ?
NO
YES
S 33
IT IS COMBINED WITH THE ALREADY OBTAINED REGION.
S 34
NO
IS AN INSPECTION OF A HIGHER PRECISION REQUIRED ?
YES
ENDS
TO THE NEXT TREE LEVEL.

FIG.19

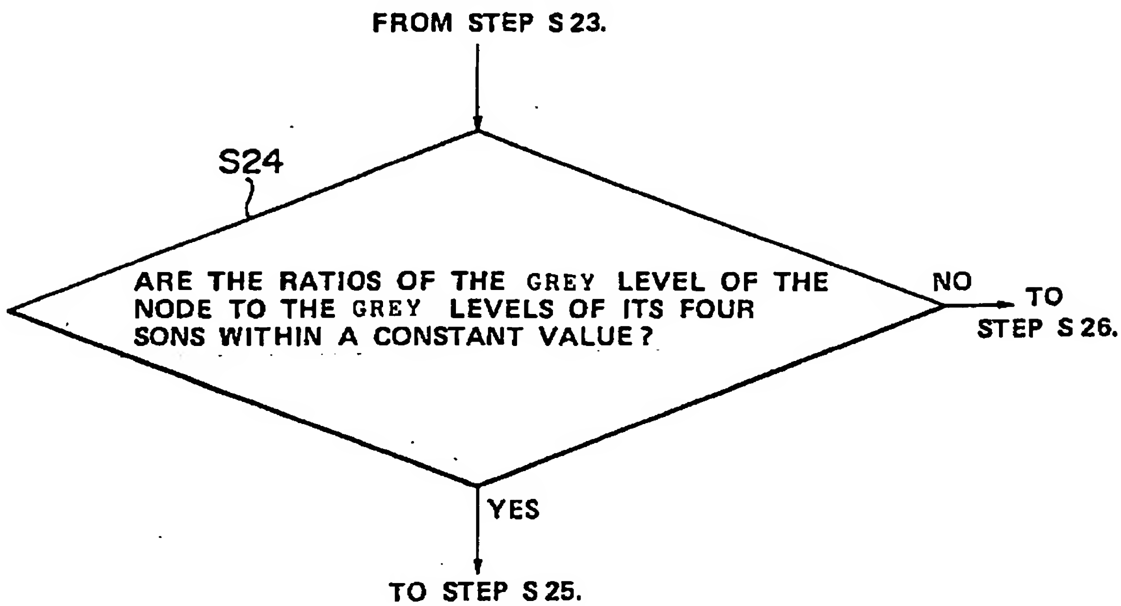
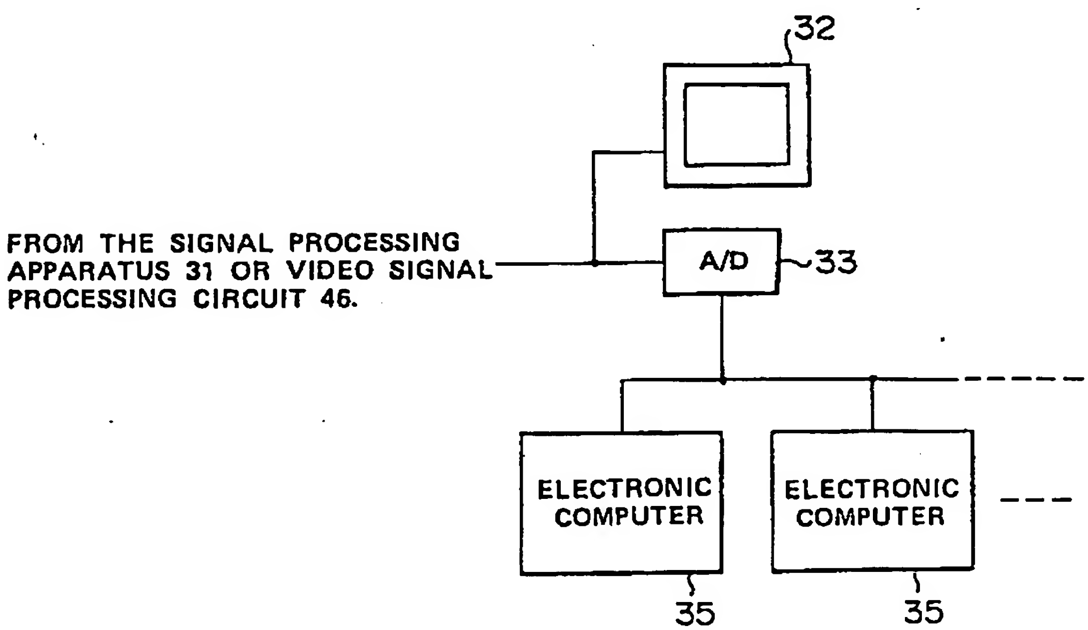

FROM STEP S 23.
S24
ARE THE RATIOS OF THE GREY LEVEL OF THE NODE TO THE GREY LEVELS OF ITS FOUR SONS WITHIN A CONSTANT VALUE ?
NO
TO STEP S 26.
YES
TO STEP S 25.

FIG.20


32
FROM THE SIGNAL PROCESSING APPARATUS 31 OR VIDEO SIGNAL PROCESSING CIRCUIT 46.
A/D
33
ELECTRONIC COMPUTER
ELECTRONIC COMPUTER
35
35

2225188

METHODS OF DETECTING ENDOSCOPE INSERTION DIRECTION:

This invention relates to methods of detecting the direction of insertion of an endoscope, particularly to methods adapted to facilitate the insertion of an endoscope in the inspection field of a large intestine, possibly by automatic control.

Recently, there has been increasing use of endoscopes to enable organs within a body cavity to be observed by inserting an elongated insertion sheath. Various curative treatments can be applied by using medical tools inserted through a treating tool channel in the sheath as required.

In a conventional endoscope inspection, the doctor judges the advancing direction of the endoscope insertion sheath by observing the endoscope image while inserting the sheath.

However, a high degree of technical skill is required to insert an endoscope sheath when inspecting the large intestine.

One object of the present invention is to provide a method of detecting the direction of insertion of the sheath of an endoscope which enables the insertion direction to be detected automatically during the treatment.

In accordance with the present invention a method of detecting the direction of insertion of an endoscope sheath comprises the steps of:

forming an endoscope display image, and providing means to construct therefrom a plurality of picture-images differing in the number of pixels (or picture elements);

selectively locating a dark region in a picture-image of a predetermined number of pixels by inspecting the picture-images sequentially in the order of less pixels to establish the grey levels of the respective pixels in the plurality of picture-images thus formed; and

finally utilising the said dark region located by the said selective step as the endoscope sheath insertion direction at that given instant.

Preferably, the forming step includes gradually forming picture-images of fewer pixels, in each of which the number of pixels is reduced by a quarter so that, for each macro-pixel formed by four subsidiary pixels of the previous picture-image, the grey level of one macro-pixel in the newly formed picture-image of fewer pixels will have an average value of the grey levels of the four subsidiary pixels arranged 2 x 2 in the previous picture-image of more pixels that have been combined to form said one macro-pixel.

Advantageously, the selective step includes inspecting the grey levels of the respective pixels in a picture-image, selecting that macro-pixel nearest to a required grey level, then inspecting the grey levels of the four subsidairy pixels of that selected macro-pixel and selecting the subsidiary pixel nearest to the required grey level.

Other features of the present invention and their advantages will become apparent from the following description with reference to the drawings, in which:-

Figure 1 is an explanatory view showing an endoscope with its insertion sheath inserted in the large intestine of a patient;

Figure 2 is a perspective view showing a tip of an endoscope insertion sheath;

Figure 3 is an explanatory detail view showing the tip of an endoscope insertion sheath at a bent part of the large intestine;

Figure 4 is an explanatory view showing the type of endoscope display image which would be seen with the endoscope sheath tip as shown in Figure 3;

Figure 5 is an explantory detail view showing the tip of an endoscope sheath inserted in a straight part of the large intestine of a patient;

Figure 6 is an explanatory view showing the type of endoscope image which would be seen with the endoscope sheath tip as shown in Figure 5;

Figure 7 is an explanatory schematic view showing details of one exemplary embodiment of an endoscope apparatus using a fibre-scope and externally fitted television camera to operate in accordance with the present invention;

Figure 8 is an explanatory schematic view showing details of one exemplary embodiment of an endoscope apparatus using a video-scope to operate in accordance with the present invention;

Figure 9 is a partial flow chart showing Step 1 of one proposed method in accordance with the present invention;

Figures 10(A) to 10(D) are explanatory views showing . picture-images or pixels as arranged on respective "floors" of a typical "quad-tree", the sequence being restricted to simplify the illustration;

Figure 11 is an explanatory view showing the node relationships of the respective "floors" of the simplified "quad-tree" shown in Figure 10;

Figures 12(A) to 12(D) are explanatory views showing examples of picture-images of the respective "floors" of the "quad-tree" of Figure 10 with typical concrete numerical grey level values indicated;

Figures 13(A) to 13(D) are explanatory views showing picture-images of respective "floors" of a typical "quad-tree" in a case where the endoscope image-display is octagonal instead of rectangular;

Figure 14 is a partial flow chart showing Steps 2 to 27 of the proposed method referred to in Figure 9;

Figure 15 is an explanatory theoretical view showing related "floors" of a "quad-tree" for explaining Step S22 of the Step 2 described in flow chart from Figure 14;

Figures 16(A) to 16(C) are explanatory views for explaining Step S24 of the Step 2 from Figure 14;

Figures 17(A) to 17(D) are explantory views showing other examples of picture-images of the respective "floors" of the "quad-tree" in which concrete numerical grey level values are indicated;

Figure 18 is a partial flow chart showing Step 3, together with the associated Steps 31 to 34 of the exemplary method, referred to in Figures 9, 14 and 15;

Figure 19 is a partial flow chart explaining details of Steps 23 to 26 of Step 2 from Figure 14; and

Figure 20 is an explanatory detail view showing a part of an endoscope apparatus as shown in Figure 7 or Figure 8, provided with a plurality of electronic computers.

First of all, a summary of the present invention will be given by way of explanation with reference to Figures 1 to 6.

As shown in Figure 1, an endoscope 1 (of the type sometimes referred to as a fibre-scope) is provided with an elongate flexible insertion sheath 2 connected to extend from a thick operating part 3. A flexible optical cable 4 extends from a side port of the operating part 3, and is provided at its end with a connector 5, which can be connected to a light output port of an illuminating source 6 containing a lamp 6a. The operating part 2 is provided at its rear end with an eye-piece 8.

As shown in Figure 2, a rigid tip 11 is supported on a curvable section 12 provided at the remote end of the insertion sheath 2. The operating part 3 is provided with a curvature-control operating knob (not illustrated) so that the curvable section 12 may be curved vertically and/or horizontally as required, by operation of this curvature-control operating knob.

An illuminating lens 15 of an illuminating optical system, and an objective lens 16 of an observation optical system are arranged in the sheath end-face, directed substantially in the same direction as the axis of the rigid tip 11. A light guide (not illustrated), for example an optical fibre bundle, is provided in the sheath 2 at the rear of the illuminating lens 15. This light guide is inserted through the insertion sheath 2, operating part 3, and optical cable 4, and is connected to the connector 5 so that, when this connector 5 is coupled to the light source 6, the illuminating light emitted by the lamp 6a enters the light guide, to be led to the tip 11 and emitted from the tip end-face to be radiated out to an object through the illuminating lens 15, as indicated in Figure 2 by solid lines, 17 representing the illuminated region.

The end-face of an image-relaying fibre bundle (not illustrated) is arranged in the image-forming plane of the objective lens 16. This image guide is inserted through the insertion sheath 2 and extends to the eye-piece 8. The object image formed by the objective lens 16 will be led to the eye-piece 8 so that it can be observed through the eye-piece lens mounted in the eye-piece 8. In Figure 2, a pair of broken-lines indicate the visual field of the observing optical system.

Now, as shown in Figure 2, the illuminating optical system and observing optical system of the endoscope 1 are adjacent to each other, and are directed in substantially the same direction. In the case where there is no other illumination, the darkest part of each endoscope image will be that farthest from the tip. Therefore, as shown in Figure 1, in the case where the endoscope 1 has its insertion sheath 2 inserted into a closed tubular member, such as the large intestine 20 of a patient, the endoscope sheath may be inserted further in the direction of the darkest region of the obtained endoscope image. This will be explained with reference to Figures 3 to 6, in which Figures 3 and 4 show one situation and its resultant image, and Figures 5 and 6 show the physical arrangement of another situation, together with the resulting image, and in Figures 4 and 6 zones of equal brightness are represented by similar shading, and the zones 21,22 and 23 show the regions in increasing order of brightness.

Figure 3 shows the insertion sheath 2 of the endoscope 1 inserted in the large intestine 20 of a patient, where it approaches an upward bend considered in the plane of the drawing. In such a case, as shown in Figure 4, the darkest part of the endoscope image will appear near the top of the image. Therefore, in this case, the

tip 11 of the endoscope 1 may be moved upward by controlled curvature of the curvable section 12 as the insertion sheath is advanced, so that the insertion sheath is guided upwards.

Figure 5 shows the insertion sheath 2 of the endoscope 1 inserted in a straight part of the large intestine 20. In such a case, as shown in Figure 6, the darkest part in the endoscope image will appear at the centre. Therefore, in this case, the insertion sheath 2 of the endoscope 1 may be advanced further, with the curvable section straight, as it is.

Thus, the method of detecting the required endoscope inserting direction is achieved by detecting the darkest region of the endoscope image, and accurately locating it.

Exemplary embodiments of the present invention will now be described with reference to Figures 7 to 20.

The proposed method can be applied, for example, using either of the embodiments shown in Figure 7 and Figure 8.

The endoscope apparatus shown in Figure 7 is provided with a fibre-scope 1 that is fed with an illuminating light from a light source 6 via a guide 4, and an externally fitted television camera 30 is coupled to the eye-piece 8 of the fibre-scope 1, which is generally as described with reference to Figure 1. The operating part 3 has an externally fitted television camera 30 provided, for example, with an image-forming lens (not illustrated) forming an image of light fed from the eye-piece 8, and a solid state imaging device (not illustrated) is arranged in the image-forming plane of this image-forming lens. This externally fitted television camera 30 drives the associated solid state imaging device, and is connected to a signal processing apparatus which forms the output signal of this

solid state imaging device into a standard video signal. The video signal output of the signal processing apparatus 31 is fed into a display monitor 32, and is also converted into digital form by an A/D converter 33 to be fed into an electronic computer 35, and possibly also into a memory (not illustrated) which may be within this electronic computer 35. The endoscope image will be displayed in the monitor 32 and the required insertion direction will be determined by the electronic computer 35.

The alternative endoscope apparatus shown in Figure 8 is provided with a video-scope 41 in place of the operating part 3 and its externally fitted television camera 30, and this video-scope 41 is coupled to the elongate flexible insertion sheath 2. A flexible optical guide 42 extends from a port in a side of the operating part 3, and is provided at its end with a connector 43 to connect to a control apparatus 45 containing a light source 6 and a video signal processing circuit 46. A solid state imaging device (not illustrated) is arranged in the image-forming plane of the objective lens at the tip of the insertion sheath 2 and is connected to the video signal processing circuit 46 within the control apparatus 45 through the signal lines inserted through the insertion sheath, operating part 3, optical guide 42 and the connector 43. The illuminating optical system of the video-scope 41 is the same as that of the fibre-scope 1, in that the illuminating light emitted from the lamp 6a of the light source 6 in the control apparatus 45 enters the light guide port. The solid state imaging device will be driven by the video signal processing circuit 46, and the output signal of this solid state imaging device will be processed to form a video signal by the video signal processing circuit. As in the endoscope using a fibre-scope, the video signal output from this video signal

processing circuit 46 is fed to the monitor 32 for display, and also converted to a digital signal by the A/D converter 33, to be fed into the electronic computer 35, and possibly taken into a memory (not illustrated) within this electronic computer 35. The endoscope image will be displayed by the monitor 32 and the required insertion direction determined in this embodiment by the electronic computer 35.

The proposed method is based upon the fact that the number of pixels in a digital form of the image is usually 512 x 512 pixels, with about 256 brightness gradations. However, in the following explanation, in order to simplify the description, the number of pixels in the original picture taken into the electronic computer 35 will be assumed to be 8 x 8, with 8 grey level gradations of 0 black gradation and 7 white gradations.

The proposed method in this first described embodiment comprises a first Step of forming, from an original picture fed into the electronic computer 35, a plurality of picture-images differing in the number of pixels - Step 1. This is followed by a Step 2 for selectively locating any dark region in each picture-image of a predetermined number of pixels, by successively inspecting the grey levels of the respective pixels in the plurality of picture-images formed by the above-mentioned Step 1 in the order of the picture-images of less pixels, and then a Step 3 combining the region within the required grey level range near the region obtained in Step 2 with the adjacent regions obtained in Step 2.

Step 1 will now be explained in detail with reference to Figures 9 to 11, and the analysis of individual pixel brightness levels, which will be referred to hereinafter as "grey levels".

As shown in Figure 9, in the case where the total pixels of the orignal picture number n x n in Step S11, an average of the grey levels of each region of 2 x 2 pixels is determined, and a picture-image of n/2 x n/2 pixels is obtained. Then, in Step S12, it is judged whether the number of pixels of the picture-image obtained in the Step S11 is or is not of the value 1. In the case where the number of pixels is not 1, the Step S11 will be repeatedly carried out on the obtained picture-images until the case is reached where the number of pixels is 1, and Step 1 will then end and the inspection will proceed to Step 2.

Thus, in Step 1, a succession of picture-images, each of less pixels, are formed until the number of pixels becomes 1, to make a so-called "quad-tree", (see Figure 11).

Step 1 is further explained with reference to Figures 10(A) to 10(D), where xij represents a pixel coordinate, (wherein x = a,b,c or d) and $\langle xij \rangle$ represents a grey level of the pixel xij.

As shown in Figure 10(D), in a Step S11 an average of grey levels of a region of 2 x 2 pixels is determined by a computation of:

$$\langle c11 \rangle = 1/4\ (\langle d11 \rangle + \langle d12 \rangle + \langle d21 \rangle + \langle d22 \rangle)$$

from an original picture (called a d-plane) assumed for simplicity to be formed of 8 x 8 pixels, d11,d12 up to d88, and, as shown in Figure 10(C), a picture-image (called a c-plane) of 4 x 4 pixels, c11,c12 up to c44, is obtained. In the same manner, as shown in Figure 10(B), a picture-image (called a b-plane) of 2 x 2 pixels, b11,b12,b21 and b22 is then obtained from:

$$\langle b11 \rangle = 1/4\ (\langle c11 \rangle + \langle c12 \rangle + \langle c21 \rangle + \langle c22 \rangle).$$

Also, as shown in Figure 10(A), a final picture-image (called an a-plane) of 1 pixel, a11, is obtained from:

$$\langle a11 \rangle = 1/4\ (\langle b11 \rangle + \langle b12 \rangle + \langle b21 \rangle + \langle b22 \rangle).$$

The above operations are nothing but forming picture-images of a resolution of 1/2 in turn.

In the thus formed "quad-tree", as shown theoretically in Figure 11, the nodes of the respective planes of a,b,c and d are related through pointers or links.

Particularly, the node of the a-plane is called a root node, and the node of the terminal (d-plane in this case) is called a leaf node.

Examples containing concrete numerical values of grey levels of respective pixels of respective picture-images obtained by the Step 1 are shown in Figures 12(A) to 12(D).

The endoscope image display area is not always square, but is often octagonal or circular, due to the light distribution characteristics of the illuminating system. Thus, in a case where it is octagonal or circular, there will be no endoscope image, but always black regions in the four corners of the picture-image. The process in such a case will now be explained for an octagonal display area, with reference to Figures 13(A) to 13(D).

As shown in Figure 13(D), for example, the left upper corner on the d-plane has an entire pixel d11, and halves of the pixels d12 and d21 that are always black regions. In such a case, if $\langle c11 \rangle$ is computed by:

$$\langle c11 \rangle = 1/4\ (\langle d11 \rangle + \langle d12 \rangle + \langle d21 \rangle + \langle d22 \rangle),$$

$\langle c11 \rangle$ will not show a correct value. In this case, if it is computed by:

$$\langle c11 \rangle = 1/3\ \{2(\langle d12 \rangle + \langle d21 \rangle + \langle d22 \rangle)\},$$

a correct value will be obtained.

A genuine dark region so rarely exists in the extreme corner that the pixels d11,d12 and d21 may be computed by:

$$\langle c11 \rangle = 1/4\ [7 + 7 + 7 + \langle d22 \rangle]$$

with the white represented by the grey level 7.

The case for an octagonal display area has been explained in detail, but the case for a circular or any other shape can be considered in exactly the same way.

In the further explanations, in order to simplify the description, the endoscope image display area will always be considered to form a square.

Step 2 will now be explained with reference to Figures 14 to 17.

As shown in Figure 14, first of all, in Step S21, a node of the value nearest to that of the required grey level is extracted from the picture-image of 2 x 2 pixels. To avoid confusion with the explanation of Step 1, in this section we will refer to the image planes of Step 1 as "floors", and the four lower node pixels formed below a pixel in one node will be termed "sons". Then, in Step S22, it is judged whether the inspection of the "floor" on which the above-mentioned Step S21 has been made may be concluded or not. In the case where the inspection of the "floor" may be concluded, in Step S23, it is judged whether the grey level of the node extracted in the above-mentioned Step S21 is in the required grey level range or not. In the case where it is in the range, then in Step S24 it is judged whether the differences between the grey level of the node extracted in Step S21 and the grey levels of the four "sons" of the node are within a constant value k or not. In a case where they are within the constant value k, the node is registered as the required region, Step 2 ends, and the inspection proceeds to Step 3.

On the other hand, in Step S22, in a case where it is judged that the inspection of the "floor" may not be concluded and, in Step S23, in a case where it is judged that the grey level is not in the required grey level range, then Step S21 and the later Steps are carried out again using the next "tree-level", that is, in the picture-image of the next largest number of pixels (the next lower "floor" in the "quad-tree"). In such a case, in the Step S21, a node of the value nearest to that of the required grey level is extracted from among the four "son" nodes corresponding to the node extracted by Step S21 in the upper "floor". Also, in Step S24, in the case where it is judged that the grey level is not within the constant value k, then in Step S26, it is judged whether the inspection has reached the lowest level of the tree to be searched, or not. In this Step S26, in case it is judged that the inspection may not be concluded, then, as described above, the Step S21 and the later Steps are carried out in the next "tree-level". Also, in Step S26, in a case where it is judged that the lowest level in the tree has been reached, then in Step S27 the inspection returns to the next higher "floor" (called a back-track) and the Step S21 and the later Steps are carried out in the order from the node of the value nearest to that of the required grey level from among the remaining three "son" nodes belonging to the same parent node as the node on which, for example, the Step S21 has already been made. If all four nodes have been tried, then the inspection continues from the next higher level, and so on.

The "floor" of which the inspection in the Step S22 may be concluded shall be explained with reference to Figure 15.

As already described, generally the number of pixels is about 512 x 512. The structure of the "quad-tree" in such a case is shown in Figure 15. In Step 2, the inspection is started from the

"floor" of 2 x 2 pixels and is advanced downward (to the "floors" of more pixels) but need not always be advanced only to the "floor" having no problem in the precision. This reduces the processing time by an electronic computer and can eliminate the influence of noise. On the other hand, for example, the "floor" of 2 x 2 pixels is too coarse. Therefore, in Step S22, the upper limit of the "floor" of which the inspection may be concluded is set in response to the required precision. In Step S26, the lowest "floor" to be searched is selected.

The Step S24 will now be explained with reference to Figures 16(A) to 16(C).

As shown in Figure 16(A), if the differences between the grey level of the hatched part of a "floor" p and the grey levels of four "son" pixels corresponding to the above-mentioned hatched part in the lower "floor" q are within a constant value, the brightness will be so uniform that there need be no further inspection of the lower "floor" r.

Therefore, in Step S24, when such a uniform state is found, no further inspection of the lower "floor" will be made. This also reduces the processing time by the electronic computer.

In Step S24, in case it is judged that the difference of the grey levels is not within a constant value k and then, in Step S26, in the case where it is judged that the inspection may be concluded, the non-uniformity of the brightness may be caused by a break in the optical fibres forming the image guide, or by noise, or non-uniformity in the image. In such case, the error can be prevented by back-tracking in the Step S27.

In this embodiment, in Step S24 it is judged whether the differences between the grey level of the extracted node and the respective grey levels of four "son" nodes of that node are within a constant value k or not. An alternate method is shown in Figure 19. In Step S24, it is judged whether the ratios of the grey levels of the respective nodes are within a constant value or not. In case the ratios are within the constant value, then Step 2 may end, but in a case where the ratios are not within the constant value, the process may proceed to the Step S26.

The operation of such Step 2 as in the above will be explained in the following by using two kinds of concrete numerical value examples.

In the first example, the grey level of the required region shall be not more than 2. The grey level distribution shown in Figure 12 will be explained by way of example. The "floor" which may be concluded will be the c-plane. The constant value k of the Step S24 shall be 1.5.

First of all, in the Step S21, the grey levels of four nodes on the b-plane are inspected. The node of the value nearest to that of the required grey level (not more than 2) is b21, which is the selected node.

Then, in the Step S22, the b-plane is judged not to be a "floor" which may be concluded.

Then, proceeding to the next "tree-level", in the Step S21, a node c32 of the value nearest to that of the required grey level is extracted from among the four nodes, c31,c32,c41 and c42, in the c-plane, corresponding to the selected note b21.

Then, in the Step S22, the c-plane is judged to be a "floor" which may be concluded.

Then, in the Step S23, the grey level of the node c32 is judged to be in the required grey level (not more than 2).

Then, in the Step S24, the grey level of the node c32 is compared with the grey levels of the nodes d53,d54,d63 and d64 in the d-plane corresponding to this node c32. The respective grey levels of c32,d53,d54,d63 and d64 are 1 to 2 and the difference is 1 and is judged to be within a constant value k = 1.5.

In the Step S25, the selected node c32 is then registered and Step 2 ends.

In the second example, the grey level of the required region shall be not more than 2 and the grey level distributions shown in Figures 17(A) to 17(D) shall be explained for example. The "floor" which may be concluded shall be the c-plane. The constant value k of Step S24 shall be 1.5.

First of all, in Step 21, the grey levels of four nodes on the b-plane are inspected. The node of the value nearest to that of the required grey level (not more than 2) is b21, which is selected.

Then, in Step S22, the b-plane is judged to be a "floor" which may be concluded.

Then, the inspection proceeds to the next "tree-level" and, in Step S21, the node c32 of the value nearest to that of the required grey level is selected from among the four nodes of c31,c32, c41 and c42 on the c-plane corresponding to the selected node b21.

Then, in Step S22, the c-plane is judged to be a "floor" which may be concluded.

Then, in Step S23, the grey level of the selected node c32 is judged to be in the required grey level (not more than 2).

Then, in Step S24, the grey level of the node c32 is compared with the grey levels of d53,d54,d63 and d64 on the d-plane corresponding to this node c32. The respective grey levels of c32,d53,d54,d63 and d64 are 0 to 2.5 and the difference is 2.5 and is judged not to be within a constant value k = 1.5.

Then, in Step S26, it is judged whether the "floor" may be concluded at the bottom or not. As the bottom "floor" may be concluded, it is then back-tracked to the Step S27. That is to say, as the node c32 is not in the required grey level range, the same inspections in and after Step S21 are made in the order from the node of the value nearest to that of the required grey level among the other three nodes c31,c41 and c42 (in the order of c42,c41 and c31 in this case), the node c42 is selected and is registered in the Step S25 and Step 2 ends.

Step 3 will now be explained in detail with reference to Figure 18.

First of all, in Step S31, the grey level of the nodes adjacent to the region obtained in Step 2 is inspected. Then, in a Step S32, it is judged whether there is a region within the required grey level range or not. In the case where there is such a region, in a Step S33, this region is combined with the region already obtained in Step 2 and Step S31 returns. The above Steps S31 to S33 are continued until there is no adjacent node within the required grey level range. On the other hand, in the Step S32, in the case where it is judged that there is no region within the required grey level range, in a Step S34, it is judged whether the inspection of a higher precision is required or not and, in case it is judged not to be required, Step 3 ends. On the other hand, in Step S34, in the case where it is judged that the inspection of a higher precision is

required, the inspection proceeds to the next "tree-level", that is, to the lower "floor" and the inspection is made near the Steps S31 to S33.

Now the operation of this Step 3 will be explained, by way of example, with the concrete numerical values shown in Figure 12.

In the inspection in Step 2, the node c32 is extracted and therefore, in Step 3, the inspection in the vicinity is made.

First of all, in the Step S31, the grey levels of the nodes of c21,c22,c23,c31,c33,c41,c42 and c43 near the node c32 are inspected. Then, in the Step S32, it is judged whether there is a region within the required grey level range (not more than 2) or not. In this example, there is no region within the required grey level range. Then, in the Step S34, in case the inspection of a high precision is required, the d-plane is more minutely inspected in the Steps S31 to S33. In this example, there is no region within the required grey level range.

Therefore, in this example, there is no region to be combined with the region obtained in Step 2.

As shown in Figure 20, if a plurality of electronic computers 35 are provided and a parallel process by the plurality of electronic computers is made in the inspection in the Steps 2 and 3, the processing time will be able to be reduced. It is one of the advantages of this embodiment using the "quad-tree" that the parallel process by the plurality of electronic computers is possible.

Thus, according to this embodiment, when the dark region selected by Steps 1 and 2 and possibly further combined by Step 3 in some cases, an endoscope insertion direction has been found.

Now, in the case where an original picture is formed of n x n pixels, when the grey level of each of the pixels is inspected, much time will be required for the inspection. Usually, n = about 512 and n x n = 262144.

On the other hand, in this embodiment, in Step 1, a "quad-tree" is made and, in Step 2, in selecting a dark region of a grey level of a value not larger than a predetermined value, a macro-inspection to a micro-inspection are made in the order of picture-images of less pixels by using the above-mentioned "quad-tree". Therefore, the processing time can be remarkably reduced.

The present invention is not limited to the above-mentioned embodiments. For example, Step 3 is not always required.

The endoscope may be inserted manually by the curvature operation and advancing insertion operation by the endoscope operator, following the endoscope insertion direction detected by the method of the present invention or it may be inserted by automatically directing the sheath tip in the detected inserting direction by the apparatus.

As explained above, according to the present invention, there is an effect that the endoscope insertion direction can be detected simply within a short processing time.

CLAIMS:

1. A method of detecting the direction of insertion of an endoscope sheath comprising the steps of:

forming an endoscope display image, and providing means to construct therefrom a plurality of picture-images differing in the number of pixels (or picture elements);

selectively locating a dark region in a picture-image of a predetermined number of pixels by inspecting the picture-images sequentially in the order of less pixels to establish the grey levels of the respective pixels in the plurality of picture-images thus formed; and

finally utilising the said dark region located by the said selective step as the endoscope sheath insertion direction at that given instant.

2. A method as claimed in Claim 1, wherein the said forming step includes gradually forming picture-images of fewer pixels, in each of which the number of pixels is reduced by a quarter so that, for each macro-pixel formed by four subsidiary pixels of the previous picture-image, the grey level of one macro-pixel in the newly formed picture-image of fewer pixels will have an average value of the grey levels of the four subsidiary pixels arranged 2 x 2 in the previous picture-image of more pixels that have been combined to form said one macro-pixel.

3. A method as claimed in Claim 2, wherein the said selective step includes inspecting the grey levels of the respective pixels in a picture-image, selecting that macro-pixel nearest to a required grey level, then inspecting the grey levels of the four subsidairy pixels of that selected macro-pixel and selecting the subsidiary pixel nearest to the required grey level.

4. A method as claimed in Claim 3, wherein the said selective step includes parallel processing using a plurality of electronic computers.

5. A method as claimed in Claim 3, wherein the said selective step includes means ending the inspection when the differences of the grey levels of the said four subsidiary pixels to that of their macro-pixel is found to be not larger than a predetermined value.

6. A method as claimed in Claim 3, wherein the said selective step includes means ending the inspection when the ratios of the grey levels of the said four subsidiary pixels to that of their macro-pixel is found to be not larger than a predetermined value.

7. a method as claimed in any preceding Claim, wherein the said forming step includes means forming a plurality of picture-images in which pixels are considered to be white in any black region lying outside the endoscope display image.

8. A method as claimed in any preceding Claim, wherein the said forming step includes means forming a plurality of picture-images removing any black region lying outside the endoscope display image.

9. A method as claimed in any preceding Claim, wherein the said selective step includes means setting the upper limit and lower limit of the "floor" at which the inspection may be concluded in accordance with a required precision.

10. A method as claimed in any preceding Claim, comprising a further step of selecting a region within a predetermined grey level range near the said dark region selected in the said selective step, and combining the said region with that said dark region.

11. A method as claimed in any preceding Claim, wherein the grey level of each said pixel is indicated by a digital amount in the said forming step and the said selective step.

12. A method as claimed in any preceding Claim, wherein the endoscope display picture-image is obtained by a television camera fitted to an eye-piece of an endoscope, whereby naked-eye observation is possible.

13. A method as claimed in any preceding Claim, wherein the endoscope display image is obtained from an imaging means provided in the endoscope.

14. A method as claimed in any preceding Claim, in which said dark region selectively located is considered to be the endoscope inserting direction following computer analysis thereof.

15. A method of detecting the direction of insertion of an endoscope sheath by computer analysis, substantially as described with reference to one or more of Figures 1 to 20.

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